

International Journal of Modern Physics A
© World Scientific Publishing Company

Studies of Open Charm and Charmonium Production at LHCb

Giulia Manca*(on behalf of the LHCb Collaboration)

*Department of Physics, University of Cagliari, Cittadella Universitaria di Monserrato, 09042
Monserrato, Cagliari, Italy*

We present recent results from charmonium and open charm production at the LHCb experiment at CERN, Geneva. We concentrate on studies for the measurement of the cross section $pp \rightarrow J/\psi X$ in its decay channel with two muons, showing the agreement of the simulation with the data in few key distributions. We also show the reconstructed modes of $D^0 \rightarrow K^- \pi^+$, $D^0 \rightarrow K^- \pi^+ \pi^0$, $\Lambda_c^+ \rightarrow p K^- \pi^+$ and $D^+ \rightarrow K_s^0 \pi^+$ and their prospects.

Keywords: LHCb, CERN, LHC, J/Psi, charm, charmonium

PACS numbers 11.25.Hf, 123.1K

1. LHC and LHCb

After a troubled start-up, the Large Hadron Collider (LHC) performed the first proton-proton collisions at a center of mass energy of 7 TeV in March 2010. Since then the accelerator has been delivering data with increasing stability and intensity, running at a steady value of instantaneous luminosity L of $1\text{--}2 \cdot 10^{29} \text{cm}^{-2} \text{s}^{-1}$ at the time of writing. So far the LHC has delivered an integrated luminosity \mathcal{L} of 16nb^{-1} of data on tape for each experiment. The LHCb experiment¹ is a forward spectrometer optimised to study the physics of B mesons. The geometry of the detector is such to maximise the acceptance for B 's, which are mainly produced in the forward region. The detector consists of a high precision vertex detector (VELO), a first Ring Imaging Cerenkov detector (RICH), RICH-1, two tracking systems located before (TT) and after (IT,OT) the dipole magnet ($B=1.4 \text{ T}$), a RICH-2, the electromagnetic and hadronic calorimeters, and the five muon stations (M1-M5). The silicon planes of the VELO are retracted during injection, but approach to within 8 mm of the beam during stable operation. The trigger consists of three levels: L0, which is purely hardware, HLT1 and HLT2, which are purely software based, with the purpose of reducing the rate from 40 MHz to 2 kHz. At the time of writing, the interaction rate is sufficiently low that only L0 and HLT1 are required.

*Giulia.Manca@cern.ch

2 Giulia Manca, LHCb Collaboration

2. J/ψ Results

Despite its first observation in 1974, the production of J/ψ particles at hadron colliders is still unclear. Several models have tried to reproduce the behaviour of the data collected e.g. by CDF-II at Fermilab²; among these, NRQCD³ is one of the most successful ones in reproducing the $p\bar{p} \rightarrow J/\psi$ cross section behaviour, but it fails to predict e.g. the polarisation. The data from the LHC experiments will be crucial in solving this puzzle. For LHCb, the J/ψ cross section measurement is a fundamental milestone towards the measurement of the B cross section and CP-violation physics, as well as an important test of the detector performance.

J/ψ 's are produced at the LHC⁴ in three main ways, directly from pp interaction ("prompt"), or indirectly through the decay of an intermediate state such as χ_c ("indirect") or from a B hadron ("delayed"). The cross section for J/ψ prompt production is of the order of $10 \mu\text{b}$ and for the delayed J/ψ about one order of magnitude smaller. The branching ratio of the $J/\psi \rightarrow \mu\mu$ is $\sim 6\%$. The muon trigger efficiency at LHCb is well above 90%. The muon reconstruction efficiency has been estimated using J/ψ events themselves as a function of the μ p_T and it is overall $(97.3 \pm 1.2)\%$ for $p_T > 6 \text{ GeV}/c$. The invariant mass distribution of $\mu^+\mu^-$ is shown in Fig. 1(left) for $\mathcal{L}=14 \text{ nb}^{-1}$. Around 4200 signal events are observed. The mass resolution is about $16 \text{ MeV}/c^2$, about 20% higher than the Monte Carlo (MC) predictions. This is expected to improve as the alignment of the detector is better understood. A "pseudo-proper time", t_z , of the J/ψ can be reconstructed, defined as $t_z = (\Delta z/p_z) \cdot M_{J/\psi}$, where Δz is the distance between the primary and secondary vertex, p_z is the component of the J/ψ momentum along the z axis, $M_{J/\psi}$ is the J/ψ mass. t_z is useful in distinguishing between delayed and prompt plus indirect J/ψ production. The t_z distribution in the data is shown in Fig. 1(right). The enhancement at positive lifetimes is indeed an indication of the presence of J/ψ from B in the sample. The acceptance for J/ψ particles has been studied with unpolarised Monte Carlo samples produced with Pythia 6.4 and found to be about 13%. We plan to measure the J/ψ production cross section in five bins of rapidity y and seven bins of p_T with $\mathcal{L} \sim 10 \text{ pb}^{-1}$. The p_T and y distributions in the data agree

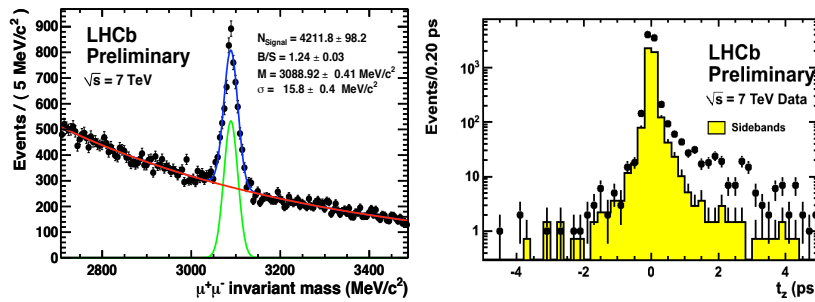


Fig. 1. Left: Invariant mass distribution of $\mu^+\mu^-$. Right: Pseudo-proper time distribution for J/ψ candidates. The enhancement at $t_z \gtrsim 3 \text{ ps}$ is due to the presence of J/ψ 's from B decays.

reasonably with the MC ones. The effect of the polarisation on the measurement has been studied in the MC and ranges between 5 and 25% depending on y and p_T .

3. Open Charm Results

Reconstruction of decays of D mesons (“open charm”) is pivotal to crucial measurements such as D^0 - \bar{D}^0 mixing or violation of Charge-Parity(CP) conservation. The $c\bar{c}$ production cross section for pp collisions at $\sqrt{s} = 7$ TeV is of the order of 5 mb, roughly ten times larger than the $b\bar{b}$ cross section at the same energy. Charm particles are produced both prompt and from B decays. At LHCb the trigger requires, in nominal conditions, energy thresholds typical of B events which results in low efficiency for triggering on charm particles. However, in this initial phase of data taking with collision rates below 25 kHz, we have been able to lower the trigger requirements to reach efficiencies $\simeq 40$ -50% for promptly produced charm particles. In 14 nb^{-1} of data we observe 6340 (1101) D^0 ’s reconstructed through their decays into $K^-\pi^+$ in untagged (tagged from the D^*) mode. The high statistics of these decays make them the ideal candidates for measurements like cross sections and D^0 - \bar{D}^0 mixing. In addition, LHCb has already managed to reconstruct decays like $D^0 \rightarrow K^-\pi^+\pi^0$, $\Lambda_c^+ \rightarrow pK^-\pi^+$ and $D^+ \rightarrow K_s^0\pi^+$. The difficulty of these channels is mainly in the experimental techniques involved in the identification and reconstruction of the decay products, particularly challenging in a busy environment like a hadron collider. The $D^0 \rightarrow K^-\pi^+\pi^0$ demonstrates high reconstruction efficiency for neutral particles, and the good functioning of the RICH used for kaon identification; the observation of $\Lambda_c^+ \rightarrow pK^-\pi^+$ is a proof of the good vertex resolution of the VELO and $D^+ \rightarrow K_s^0\pi^+$ shows the ability of reconstruct particles also with just one track close to the vertex.

4. Conclusions and Outlook

The charm program at LHCb has just started and already looks extremely promising. With all the tools into place we have set the basis for the J/ψ cross section measurement, which is a crucial step in the understanding of the detector as well as an important physics result which could solve existing open issues in QCD. We have observed several open charm decay modes such as $D^0 \rightarrow K^-\pi^+$, important for the D^0 - \bar{D}^0 mixing measurement, which we expect to produce the world-best measurement with 100 pb^{-1} of data. With the same luminosity we also expect to set competitive limits on rare charm decays like $D^0 \rightarrow \mu^+\mu^-$.

References

1. The LHCb Collab., *JINST* **3**, S08005 (2008).
2. The CDF-II Collab., *Phys.Rev.Lett.* **79**, 572(1997); *Phys.Rev.Lett.* **79**, 578(1997).
3. W.E.Caswell, *Phys.Lett.B* **167**,437(1986); G.P.Lepage, *Phys.Rev.D* **46**, 4052(1992).
4. N. Brambilla *et al.*, hep-ph/0412158.